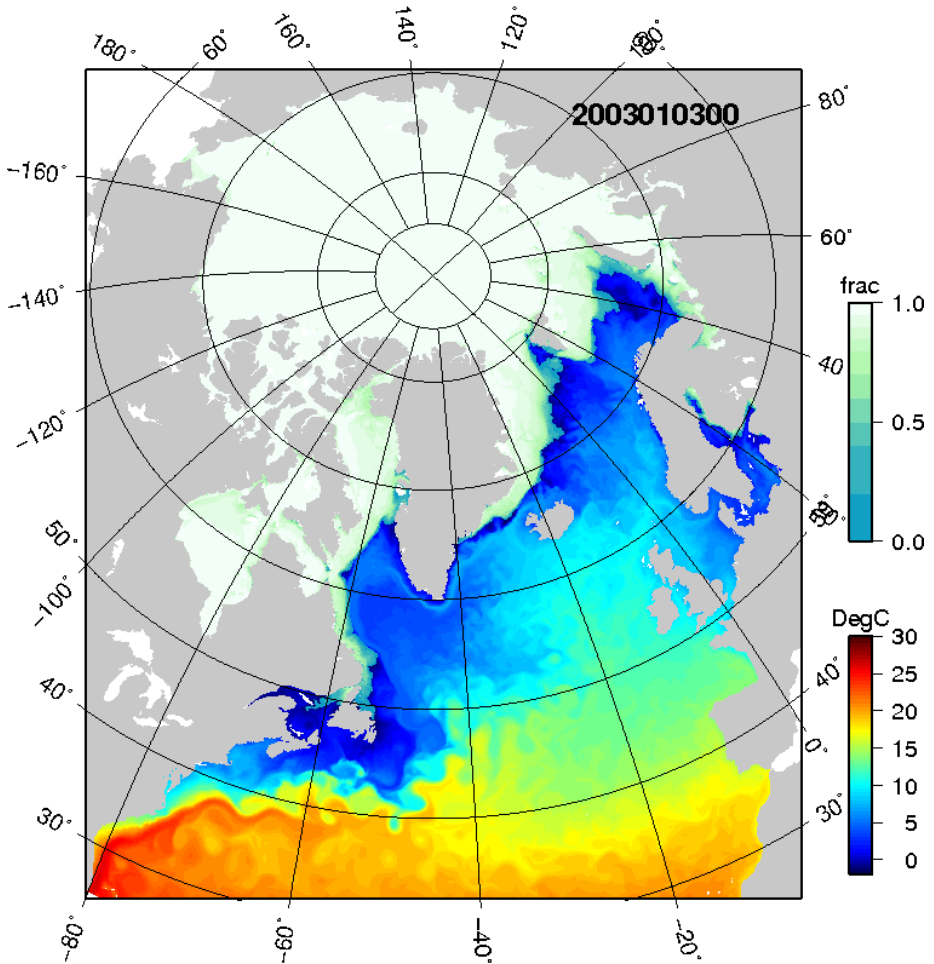
# ECCC modeling activities using CICE

**J.-F. Lemieux, F. Roy, F. Dupont, G. Smith...**

*Environment and Climate Change Canada,*
*Dorval, Québec, Canada*




Environment Canada

# ECCC ice-ocean-atmosphere forecasts

Our modeling activities are mainly in Dorval (Montréal), QC and Victoria, BC.

- short-term (Montréal)
- seasonal (Montréal and Victoria)
- climate (Victoria)

# All our (Montréal) forecasting systems are based on

- GEM (Canadian atmospheric model)
- NEMO (ocean)
- CICE

Our operational systems use CICEv4.0. We are currently using CICEv5.1.2 in R&D.

# Why do we need sea ice forecasting?

- Navigation (ice conditions, ice pressure)
- Emergency response (S&Rescue, oil spills)
- Planning of human activities
- Weather forecasting
- Seasonal forecasting

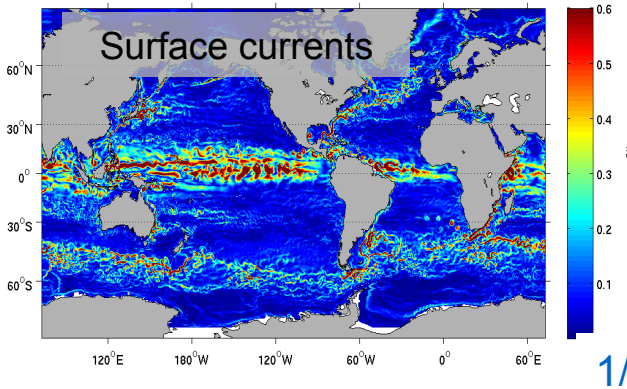
# Ice-ocean modelling with NEMO CICE

Operational
Experimental
In development

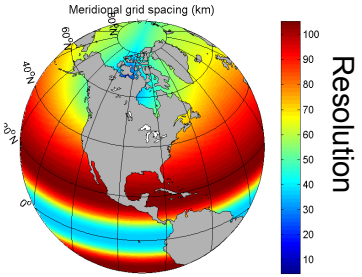
## Applications and domains

- Global 1/4° resolution (GIOPS)
  - Medium-monthly forecasting
  - Fully-coupled for NWP
- Global 1° resolution (CanSIPS-GN)
  - Seasonal forecasting
- N. Atlantic and Arctic 1/12° (RIOPS)
  - Short-to-medium range forecasting
- East and West Coastal 1/36° (CIOPS)
- Great Lakes 2km (RMPS-GL)
- Gulf of St. Lawrence 5km (RMPS-GSL)
  - Short-term forecasting

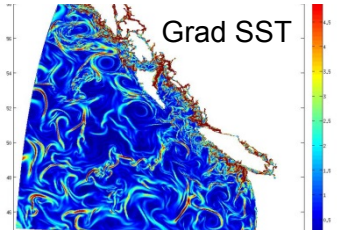
1/4° Global



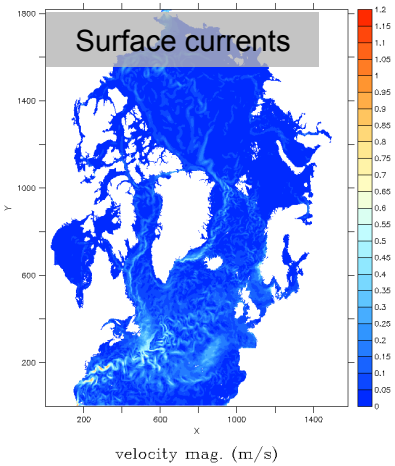

1° Global



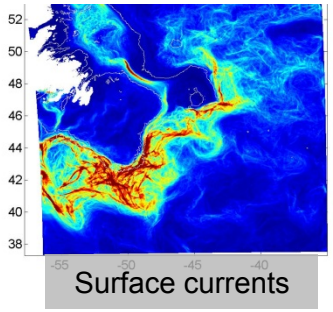

1/36° Northeast Pac.

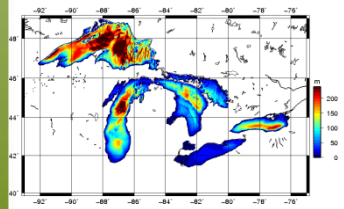


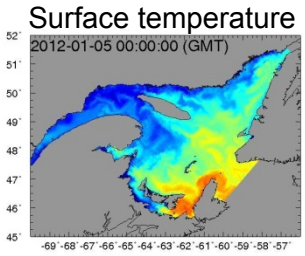

1/12° N. Atlantic and Arctic




1/36° Grand Banks

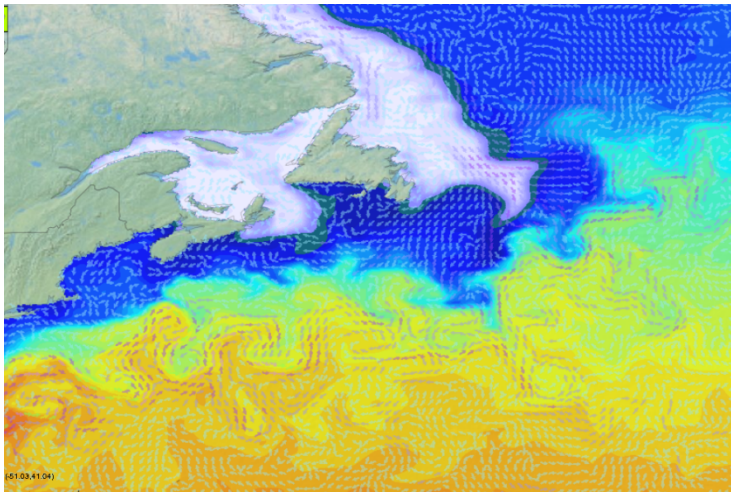


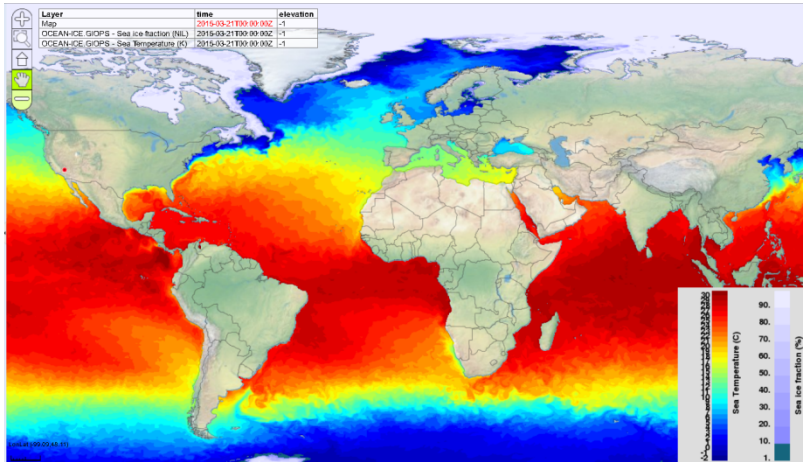



# Global Ice-Ocean Prediction System (GIOPS)

- Produces daily ice-ocean analyses and 10day forecasts
  - NEMO-CICE (~1/4°), < 15km in Arctic
- Mercator Ocean Assimilation System (SAM2):
  - Sea surface temperature
  - Temperature and salinity profiles
  - Sea level anomaly from satellite altimeters
- 3DVar Ice analysis:
  - SSM/I, SSM/IS, CIS charts, Radarsat image analyses
- Purpose:
  - Boundary conditions for regional systems
  - Initialize seasonal forecasts
  - Emergency response
  - Global coupled forecasting

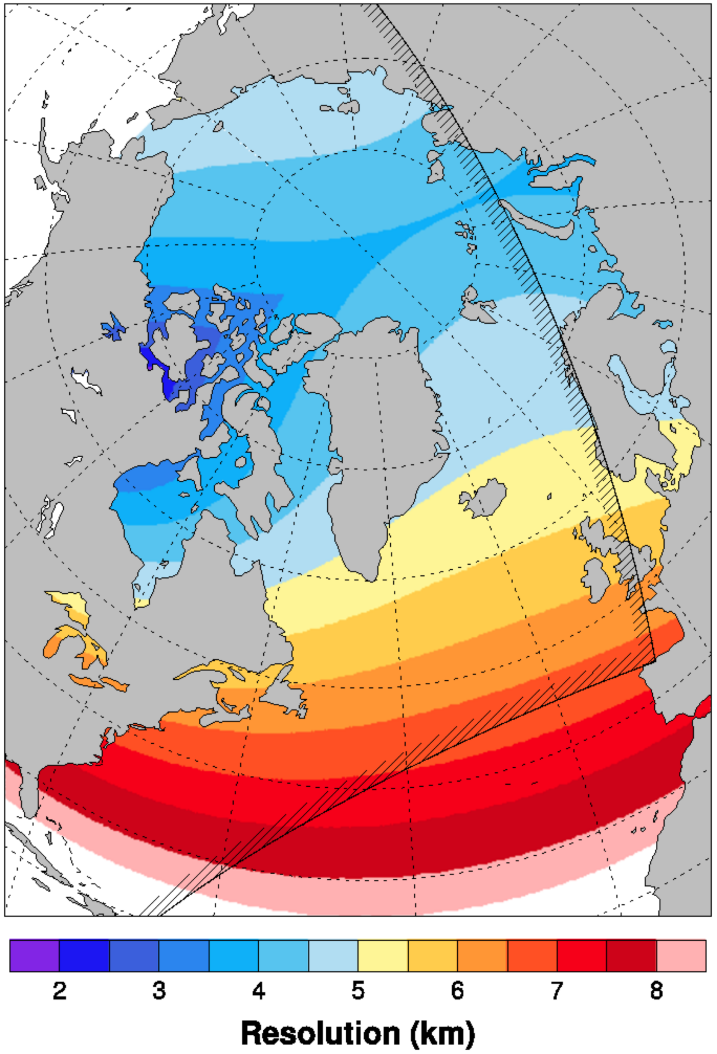





Smith et al., QJRMS, 2015

# Regional Ice Ocean Prediction System (RIOPS)

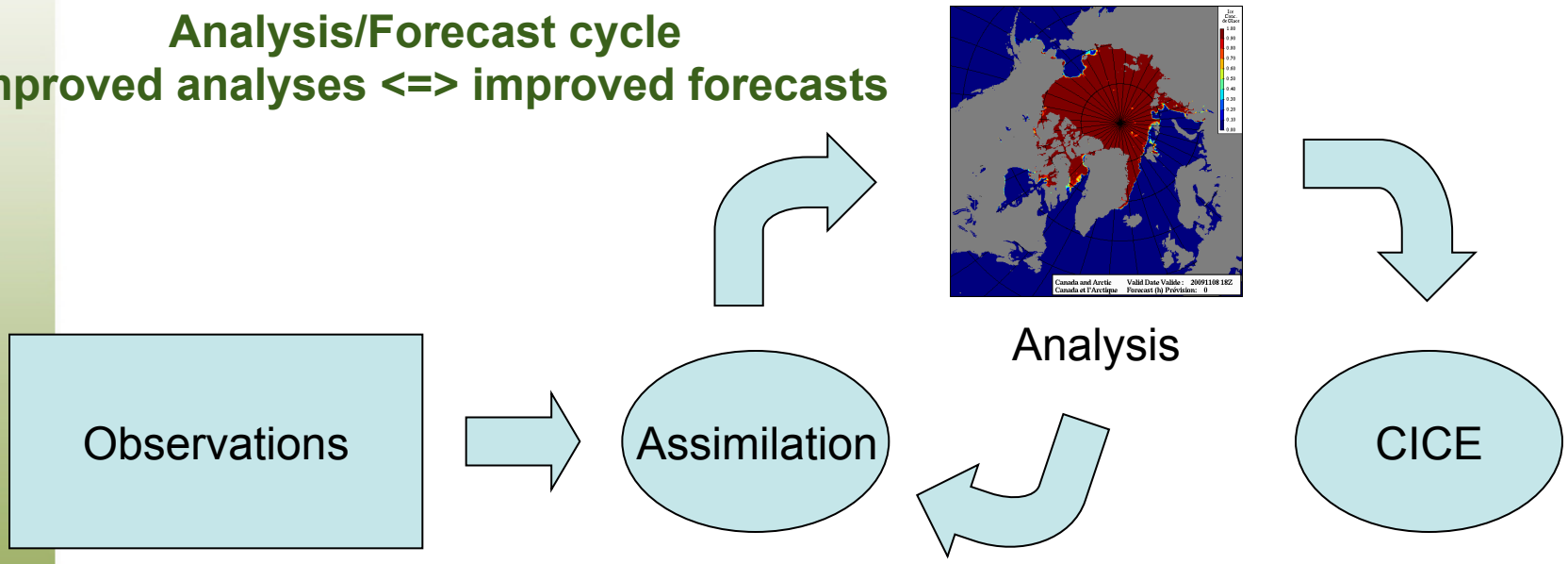
- Produces 4x 48h forecasts per day
  - NEMO-CICE (~1/12°) with tides
- 3DVar Ice concentration analysis:
  - SSM/I, SSM/IS, CIS charts, Radarsat image analyses
- Forced by EC 10 km atmospheric forecasts and by GIOPS surface currents
- Spectral nudging to GIOPS ocean analysis
- Forecast fields:
  - ice concentration, thickness dist
  - ice velocity
  - ice pressure




Lemieux et al., QJRMS, 2015
Dupont et al., GMD, 2015

# Evolution towards an NWP-like Approach to Sea-Ice Analysis/Prediction

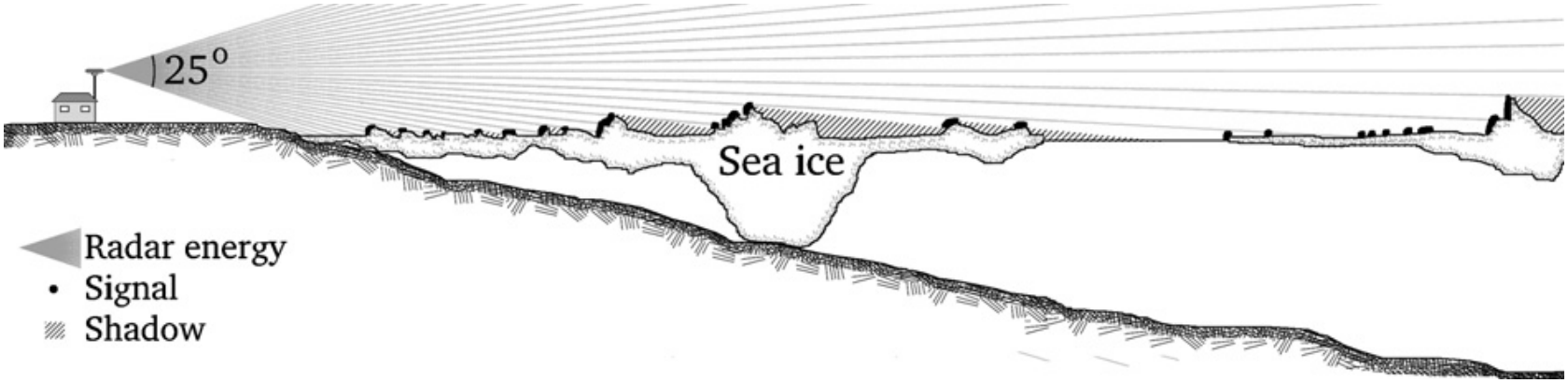
**Analysis/Forecast cycle**
**Improved analyses <=> improved forecasts**



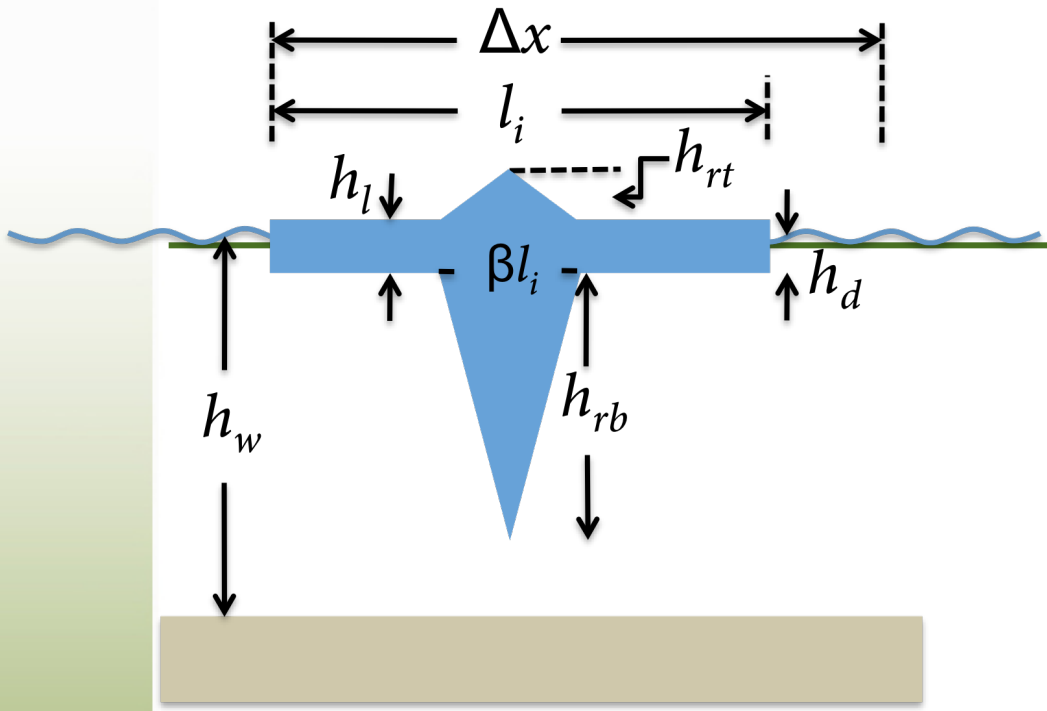

Shlyaeva et al., QJRMS, 2016

# Our recent code developments

# Grounding scheme for modeling landfast ice




Mahoney et al. 2007

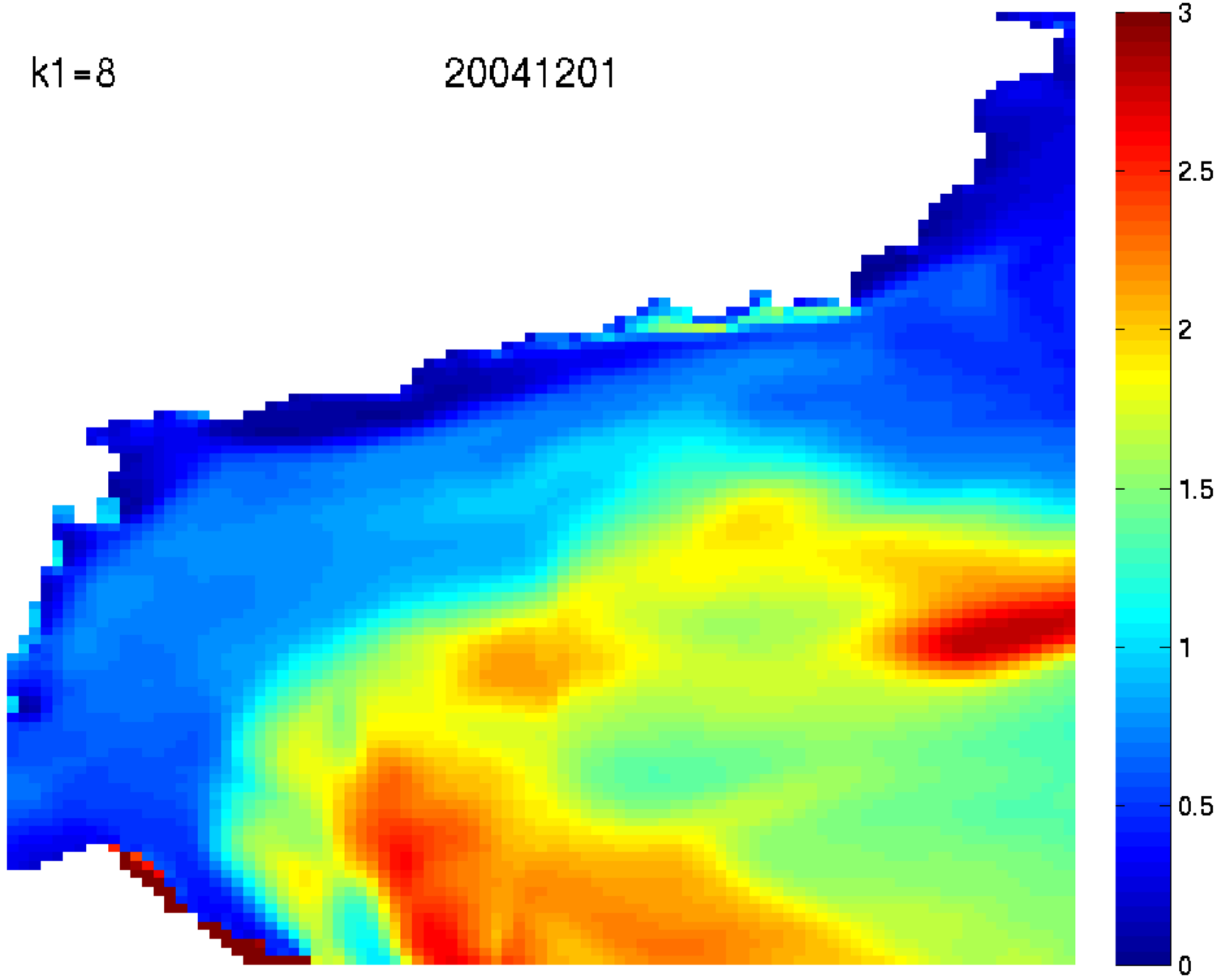



$$h_c = \frac{A h_w}{k_1}$$

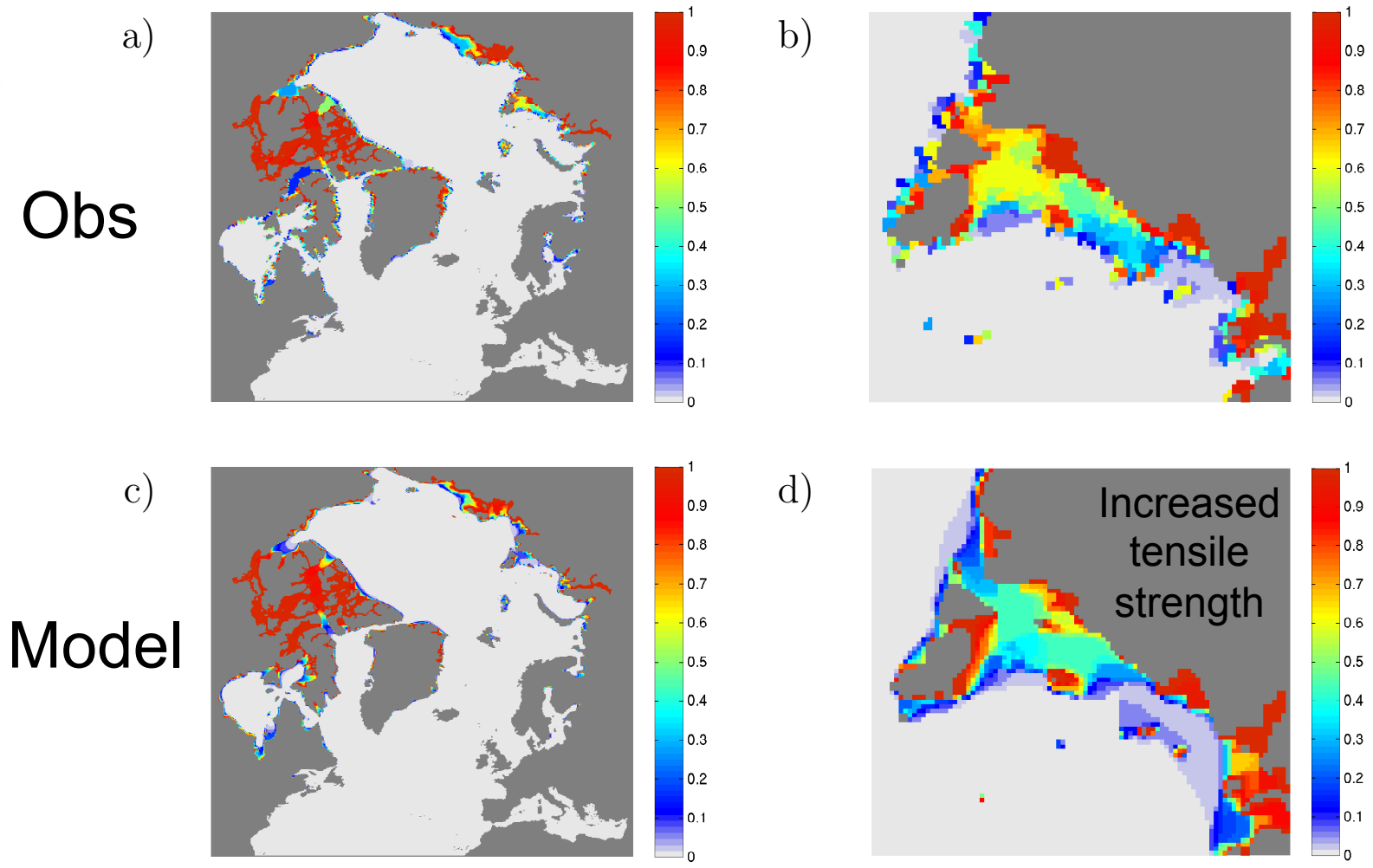
$$\tau_b = 0 \qquad \text{if} \quad h \le h_c$$

$$\tau_b = k_2 \frac{u}{\left(|u| + u_0\right)} (h - h_c) \qquad \text{if} \quad h > h_c$$

Lemieux et al., JGR, 2015

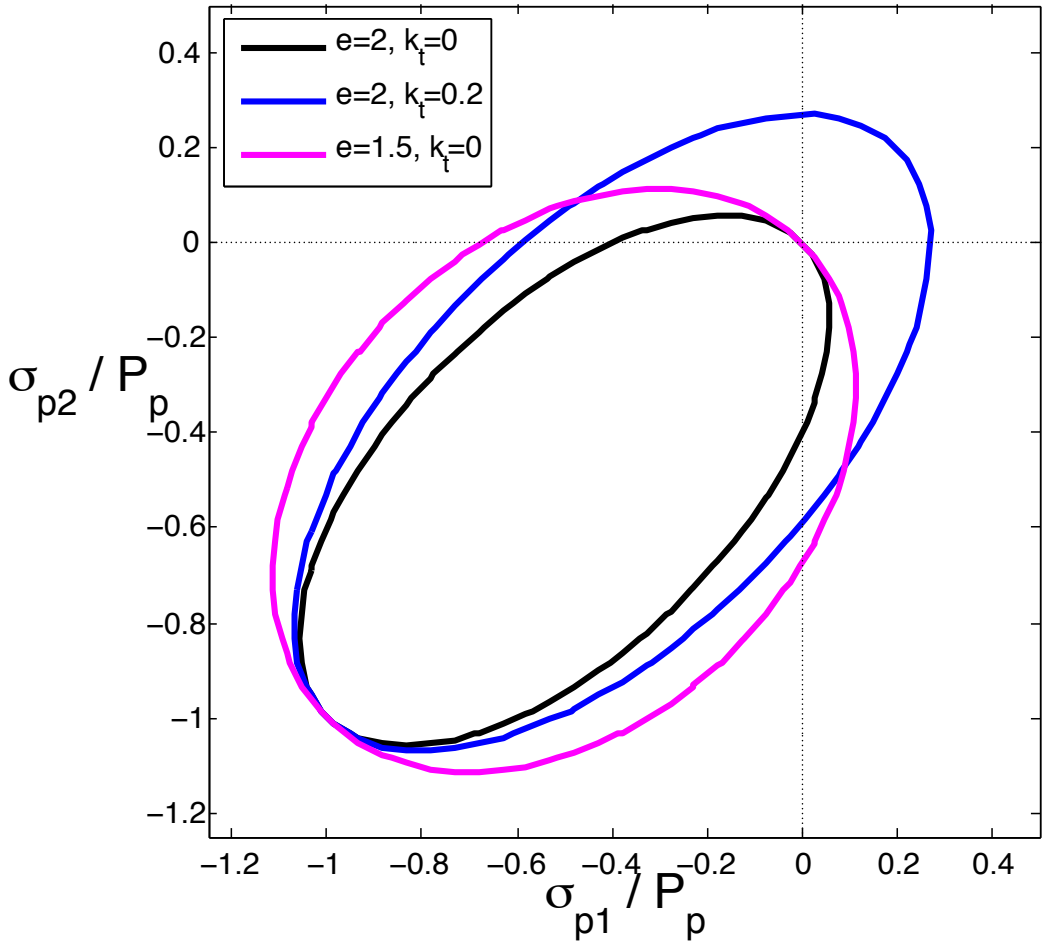

k1=8
20041201
3
2.5
2
1.5
1
0.5
0

# Observed and simulated frequency of occurence



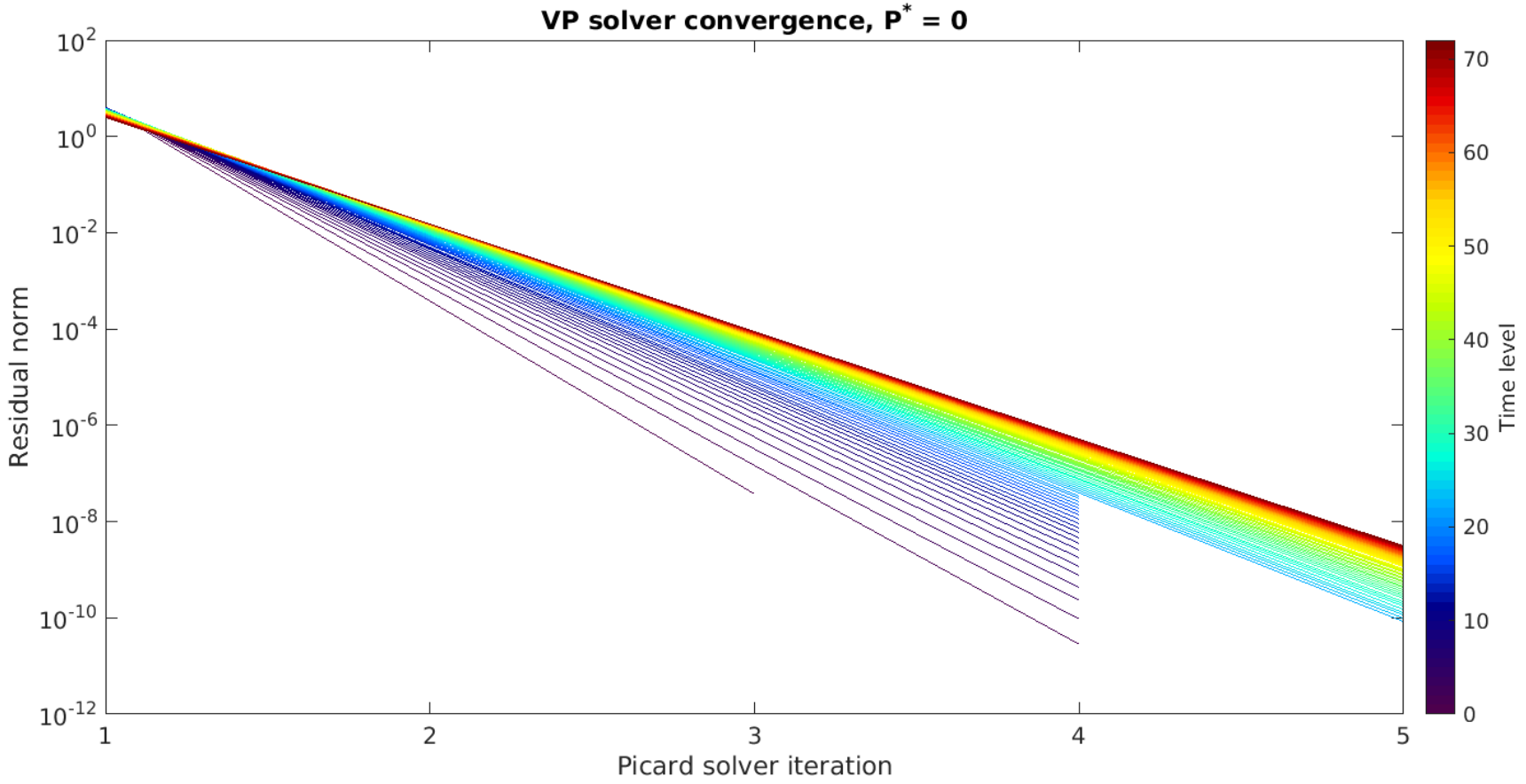

Lemieux et al., 2016

# Modification of rheology to enhance tensile strength




Konig and Holland, 2010

# Implicit solver for the momentum equation



# Canadian collaborations

- Bruno Tremblay (McGill)
- Dany Dumont (UQAR, MEOPAR)
- CONCEPT (ECCC-DFO-DND)

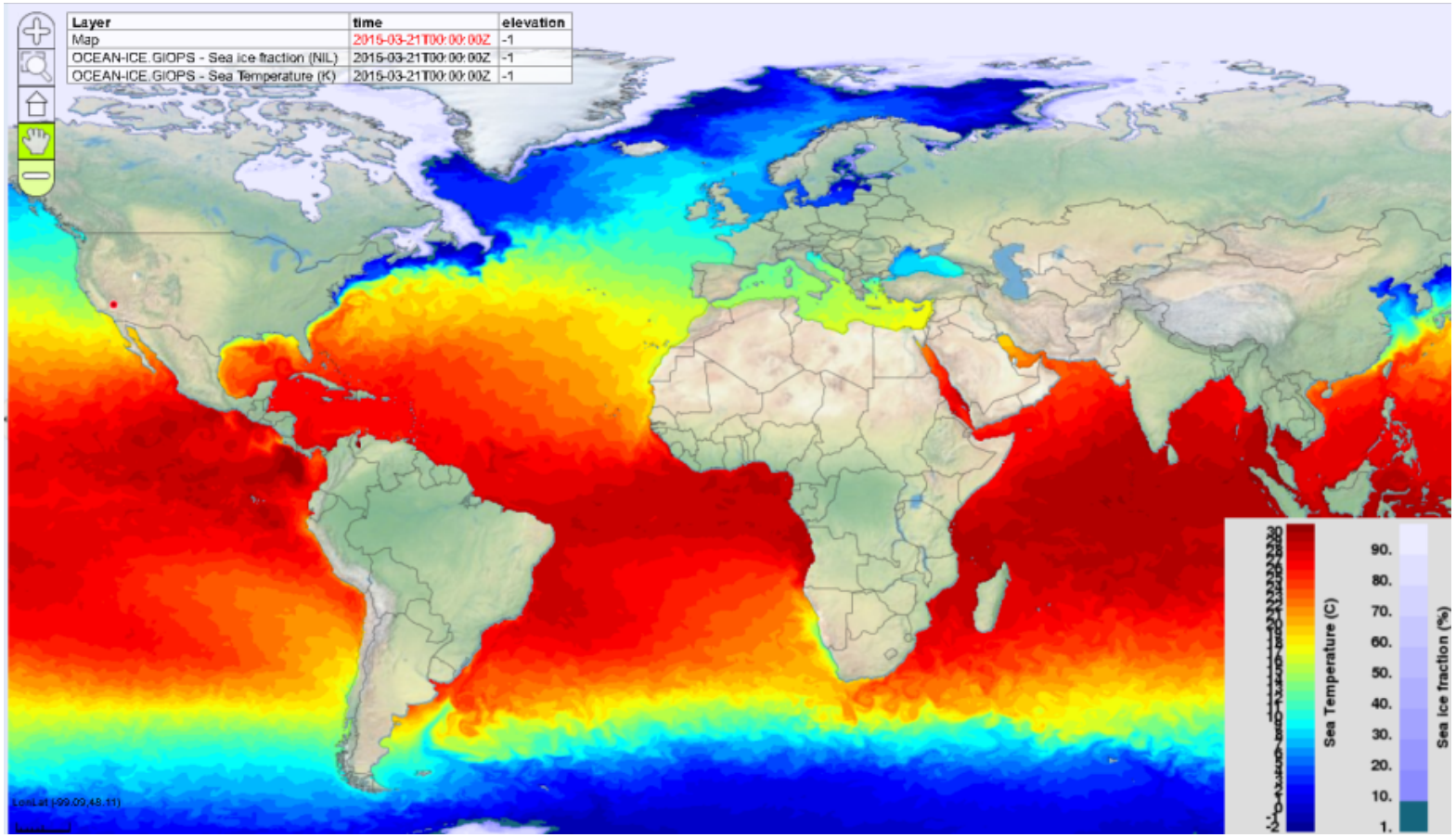
# Our requirements and needs

- As we use NEMO, we need structured grids for our ice-ocean configurations.
- Important for us to have the latest developments done by the community (e.g. form drag).
- As we are going toward ensemble forecasting, we might need stochastic physics in CICE.
- Code optimization (going toward 1/12° global)

# Our possible tasks with the consortium

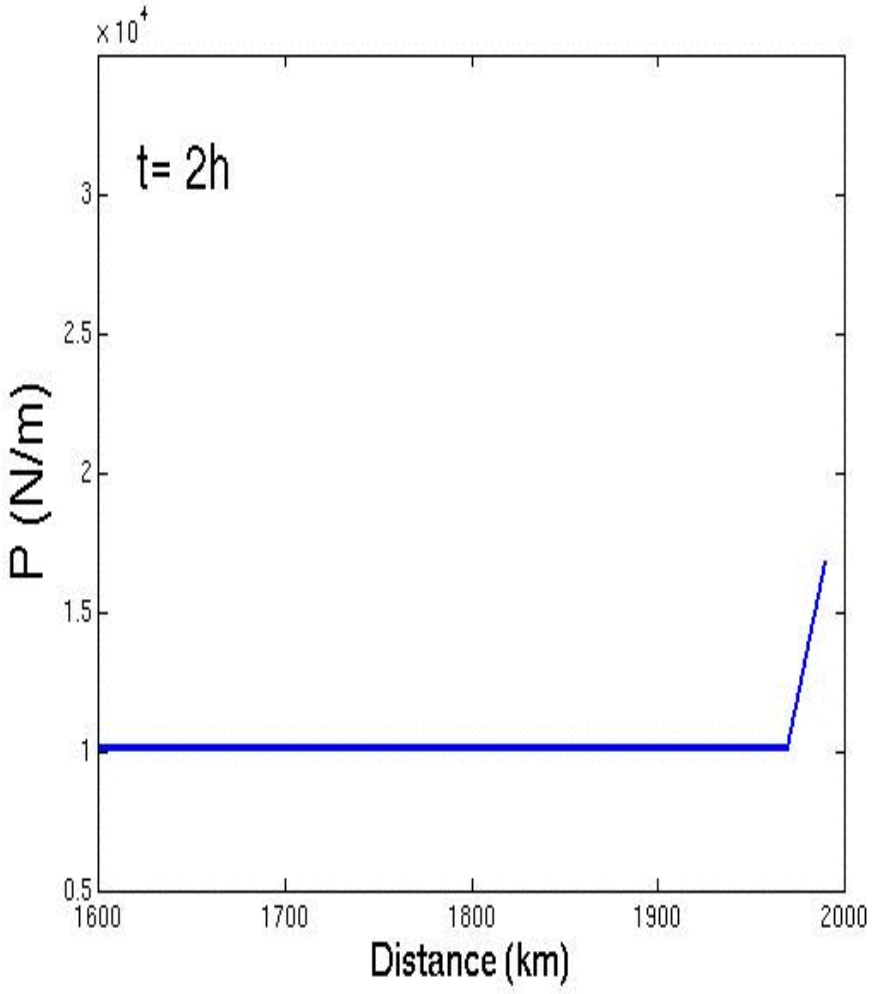
- Logo
- Dynamics box (part of Dycore)

# Thank you!

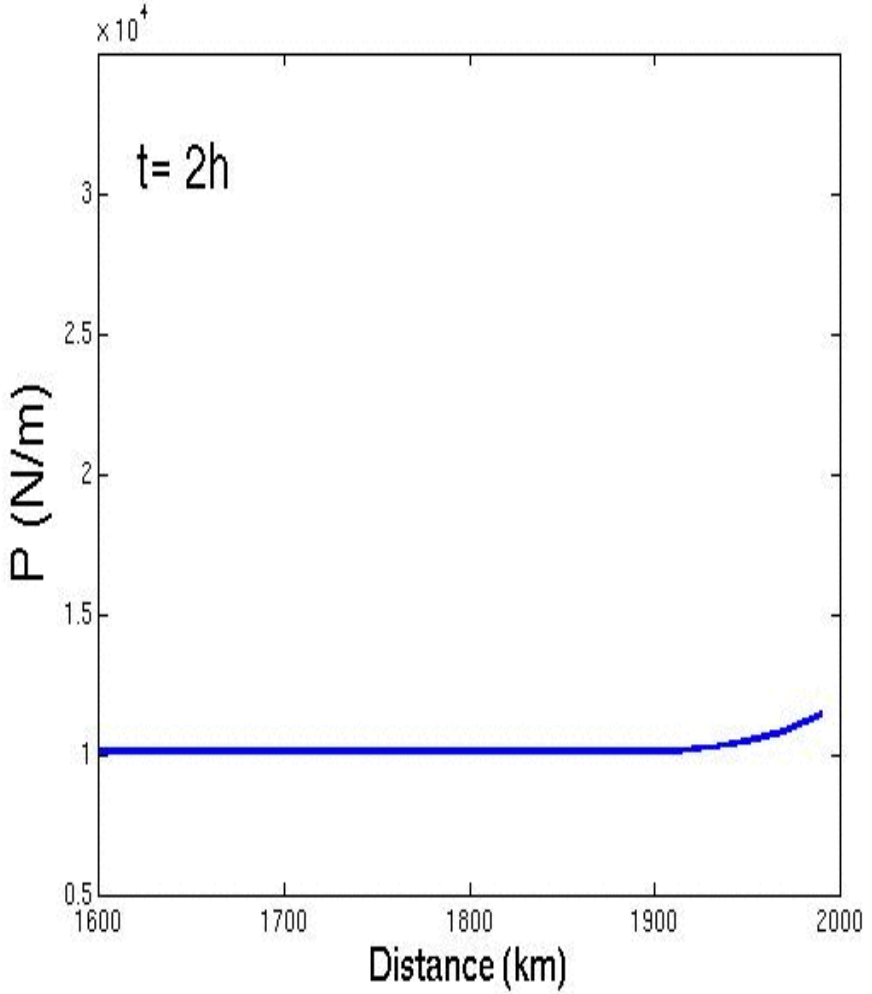

Layer
time
elevation
Map
2015-03-21T00:00:00Z
-1
OCEAN-ICE.GIOPS - Sea ice fraction (NIL)
2015-03-21T00:00:00Z
-1
OCEAN-ICE.GIOPS - Sea Temperature (K)
2015-03-21T00:00:00Z
-1
Sea Temperature (C)
90.
80.
70.
60.
50.
40.
30.
20.
10.
1.
Sea ice fraction (%)

# 1D experiment

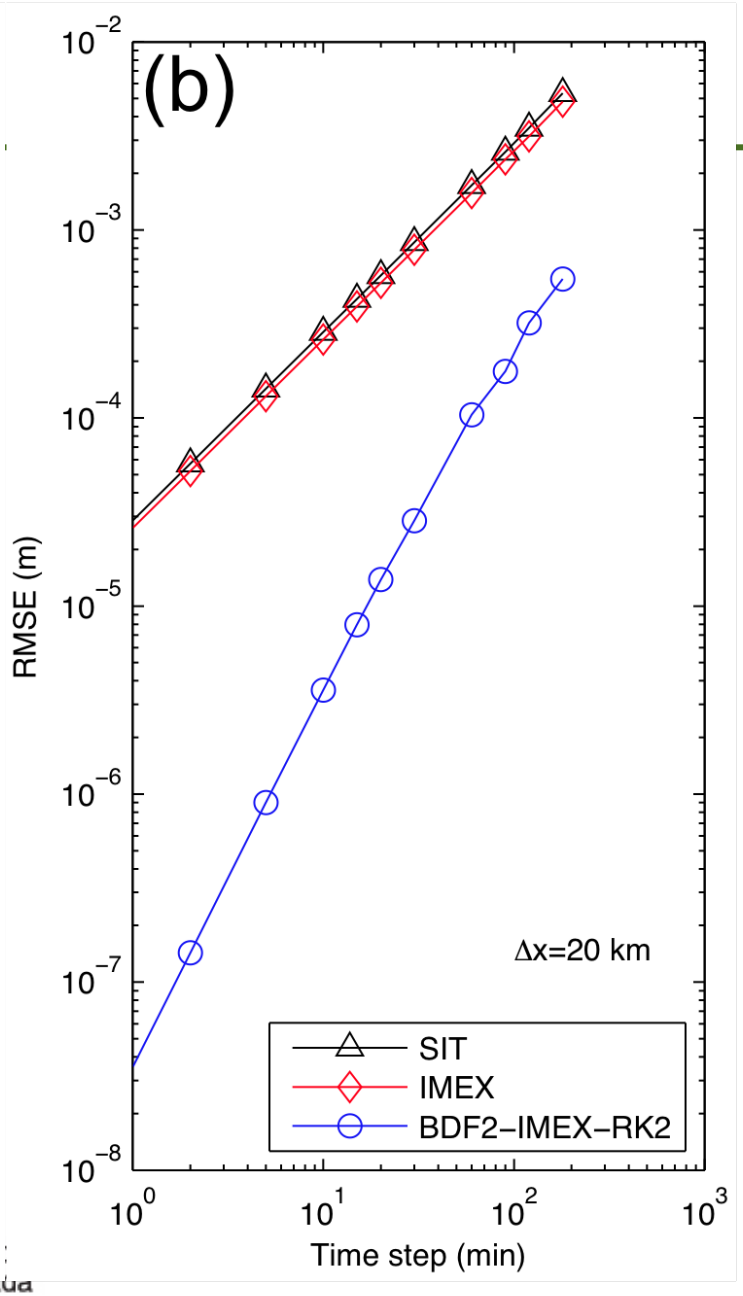
## SIT



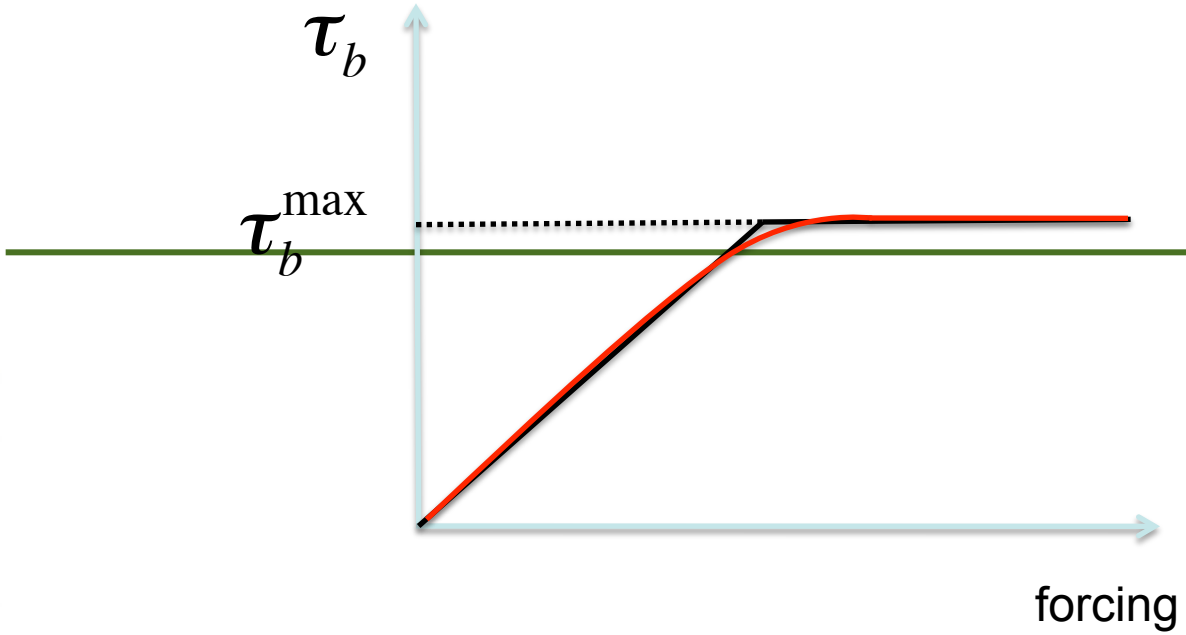

## BDF2-IMEX-RK2



# RMSE (thickness) after 1 day




Lemieux et al., JCP, 2014

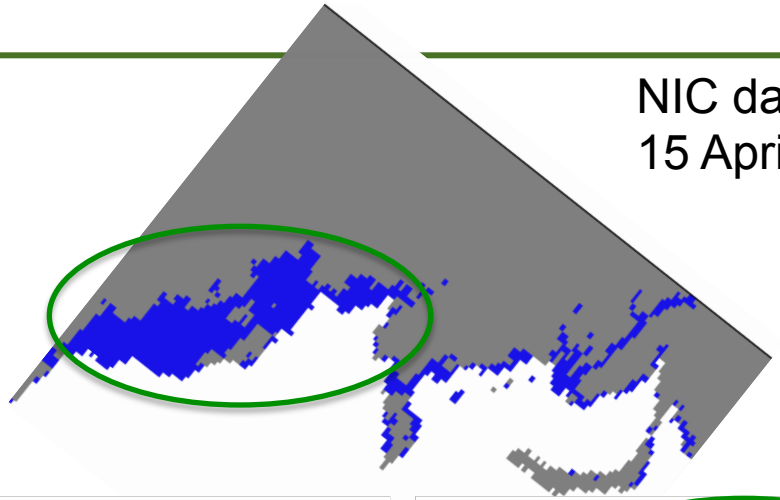



$$h_c = \frac{Ah_w}{k_1}$$

$$\tau_b = 0 \qquad \text{if} \quad h \le h_c$$

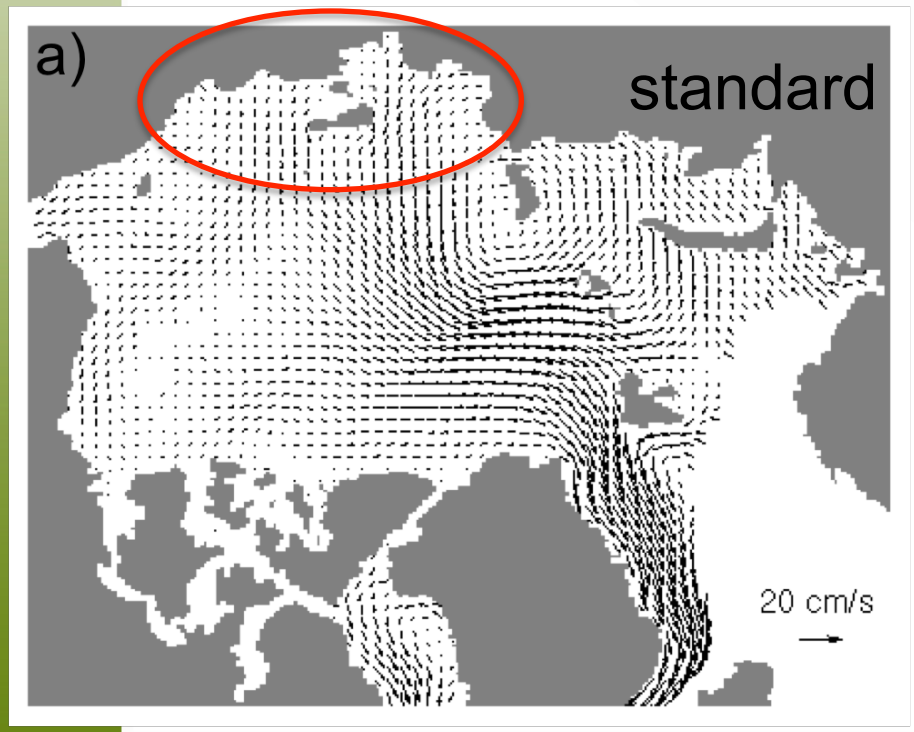
$$\tau_b = k_2 \frac{u}{\left(|u| + u_0\right)}(h - h_c) \qquad \text{if} \quad h > h_c$$

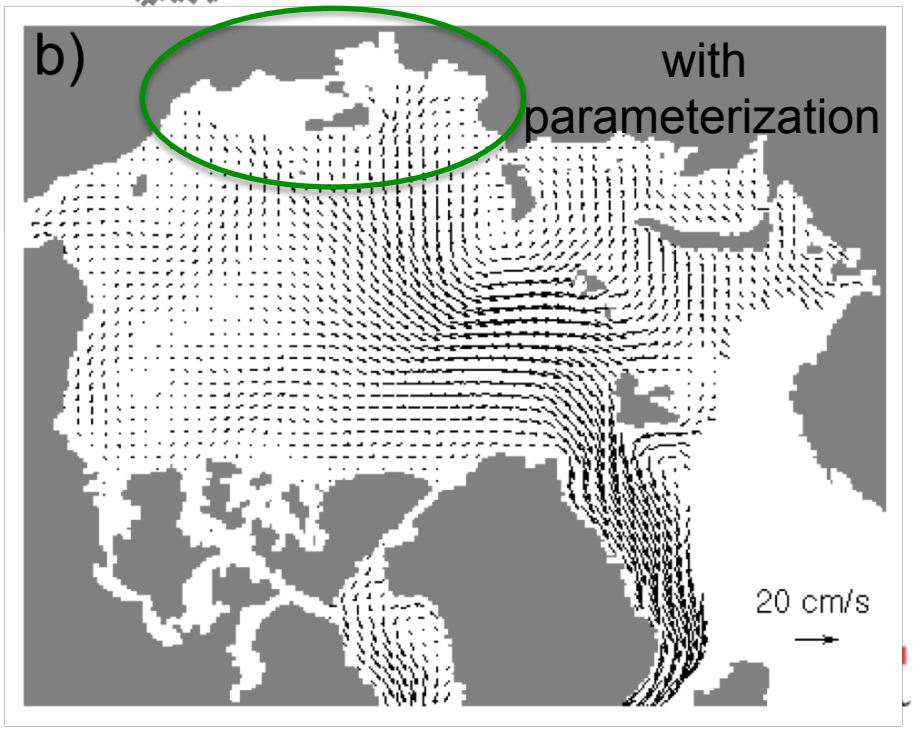
# The model with the parameterization versus the standard model (April 2002)



NIC data
15 April 2002

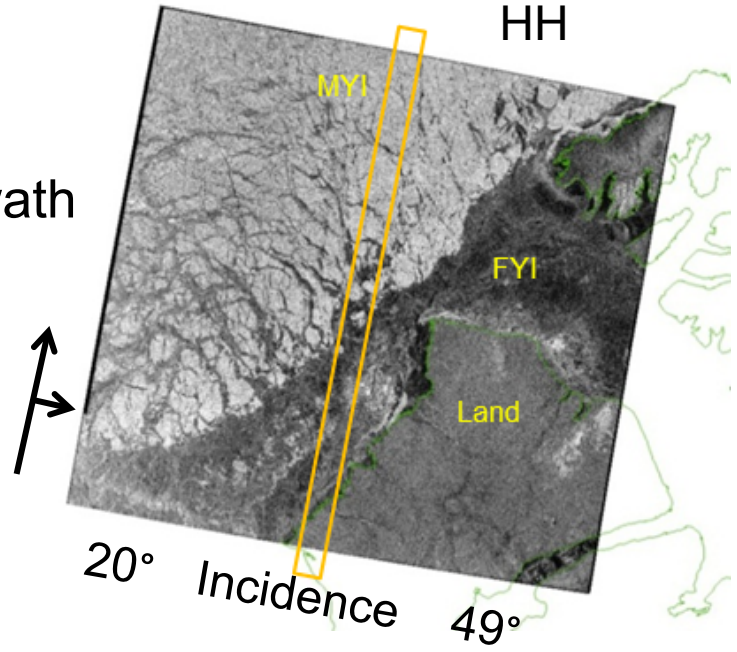
Lemieux et al. 2015

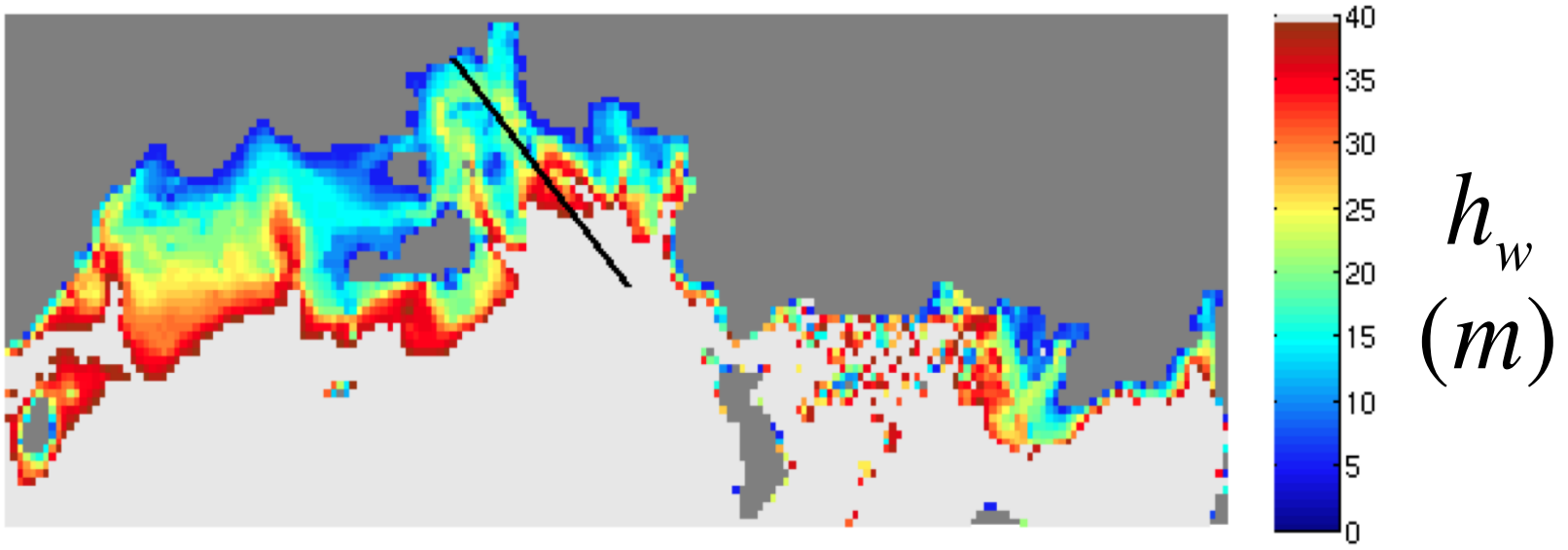


# SAR data assimilation

- SAR data used
  - ScanSAR Wide-A
    - 50 m pixel-spacing, 500 km swath
    - HH and HV polarizations
- Challenges
  - SAR backscatter varies with
    - Incidence angle
    - Ice type
    - Ice surface conditions
    - Wind speed (and direction) for open water
    - SAR noise floor

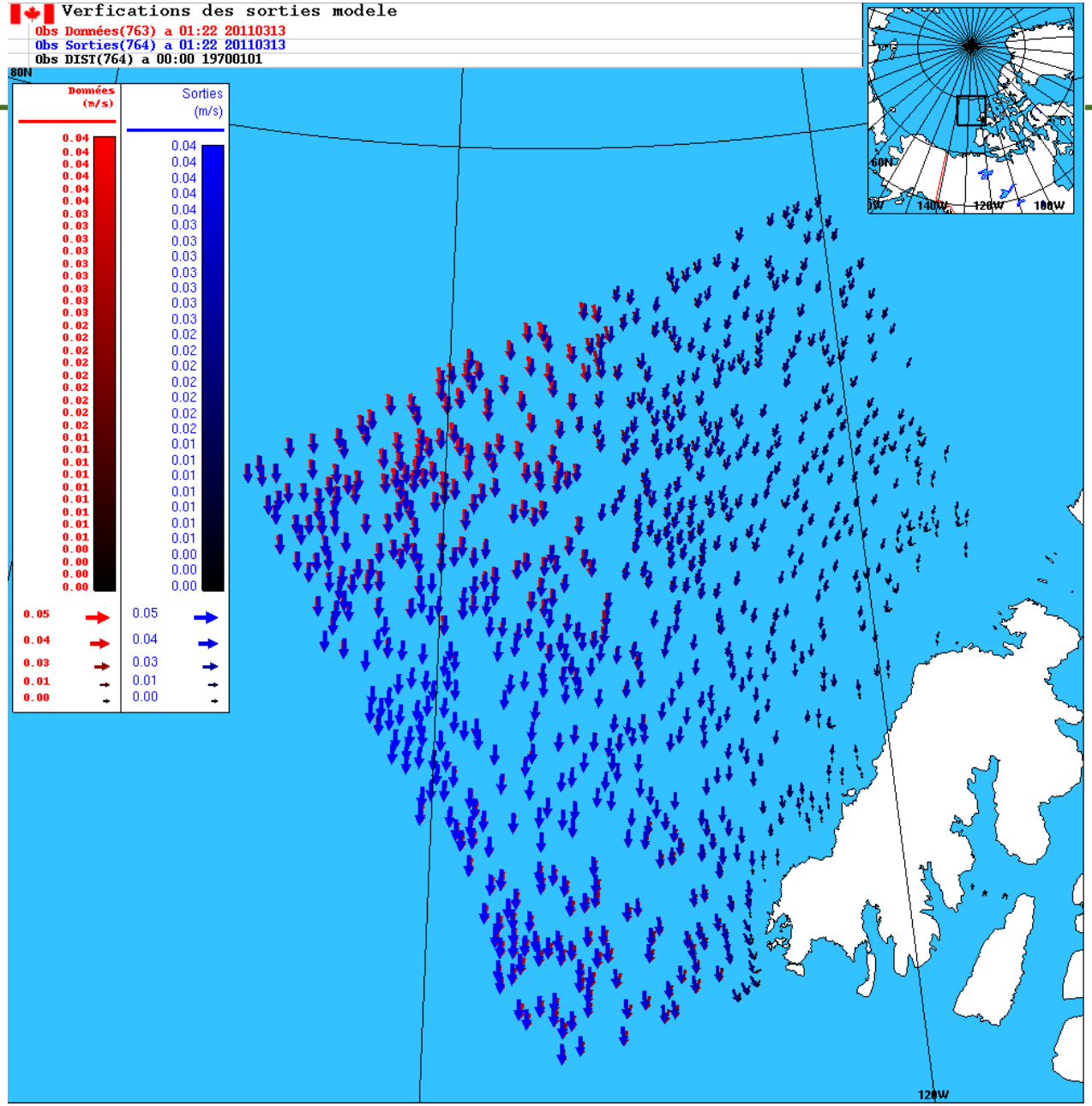



40
35
30
25
20
15
10
5
0
$h_w$
$(m)$

# Comments on the development of short-term sea ice forecasting systems.

- combination of hindcast and forecast mode.
- constant comparison with obs.

# Verification of forecast ice velocity



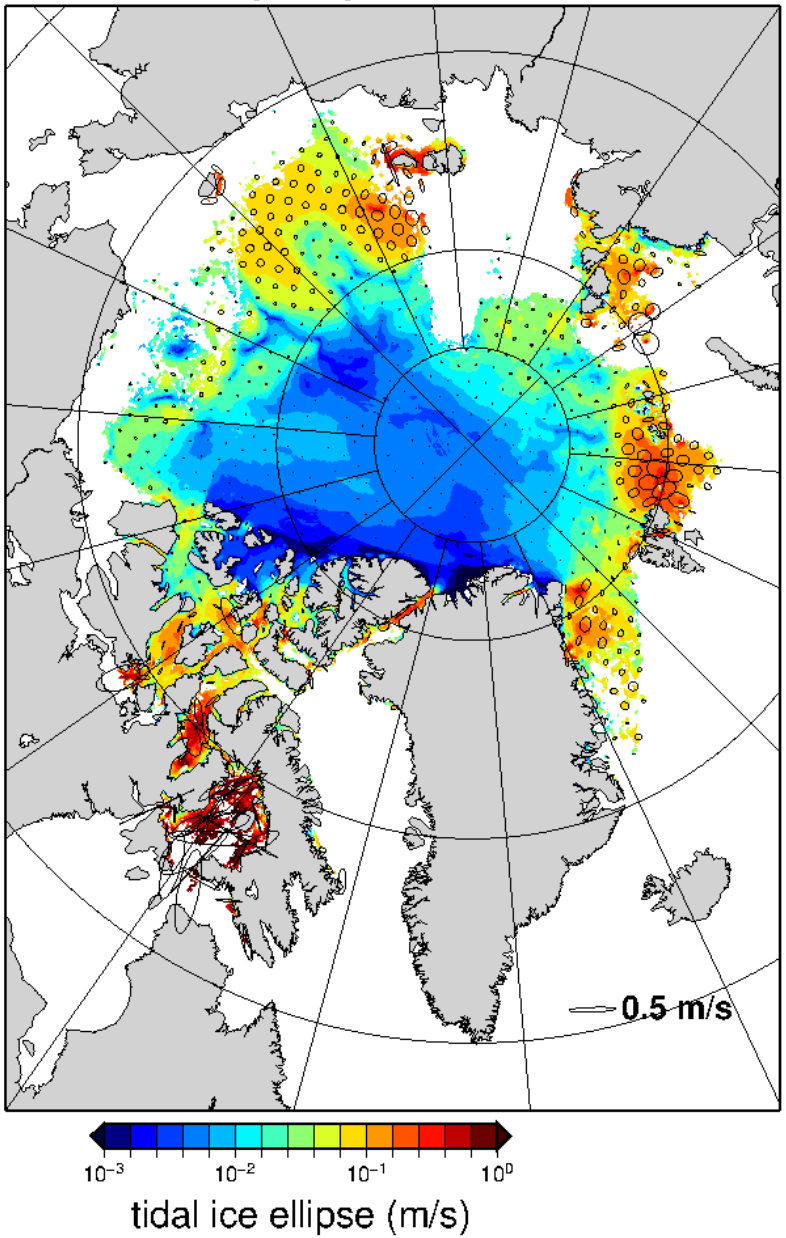

Komorov and Barber 2014

Canada

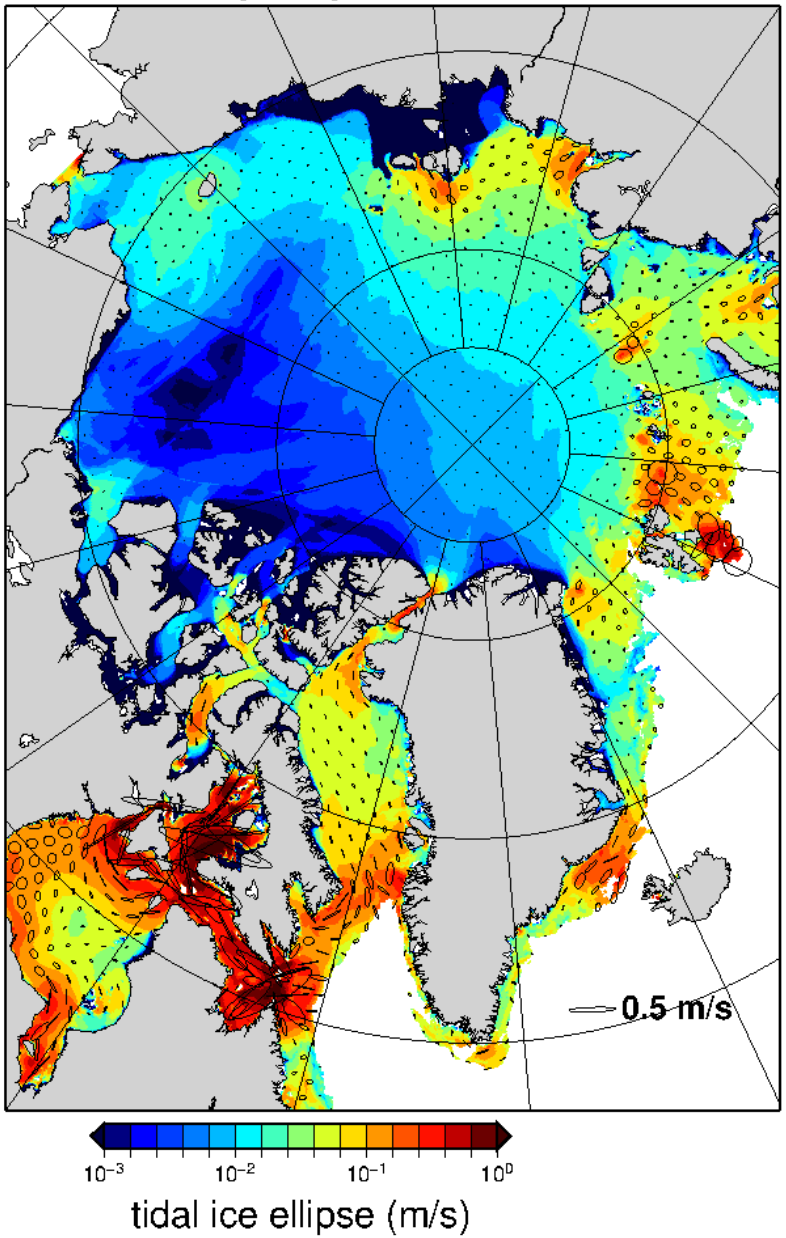
# DA challenges

- SSMI/SSMIs issue with wet ice-melt ponds
- Narrow channels (large footprint and land contamination), higher uncertainty zones...
- Wind filter to eliminate spurious ice concentration retrievals from passive microwave data

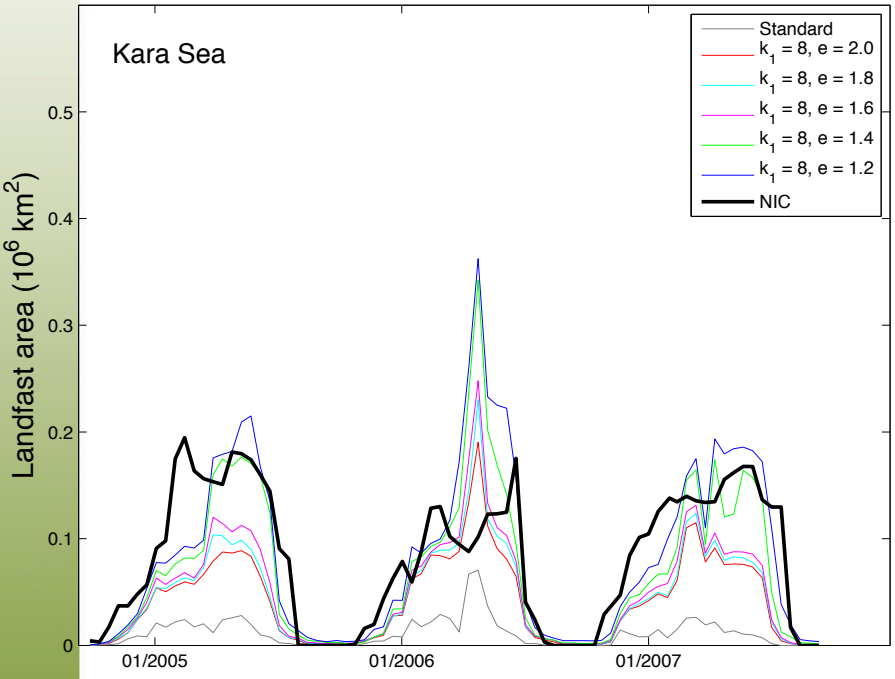
## Summer (July) 2014 tidal ellipse (M2) in the ice

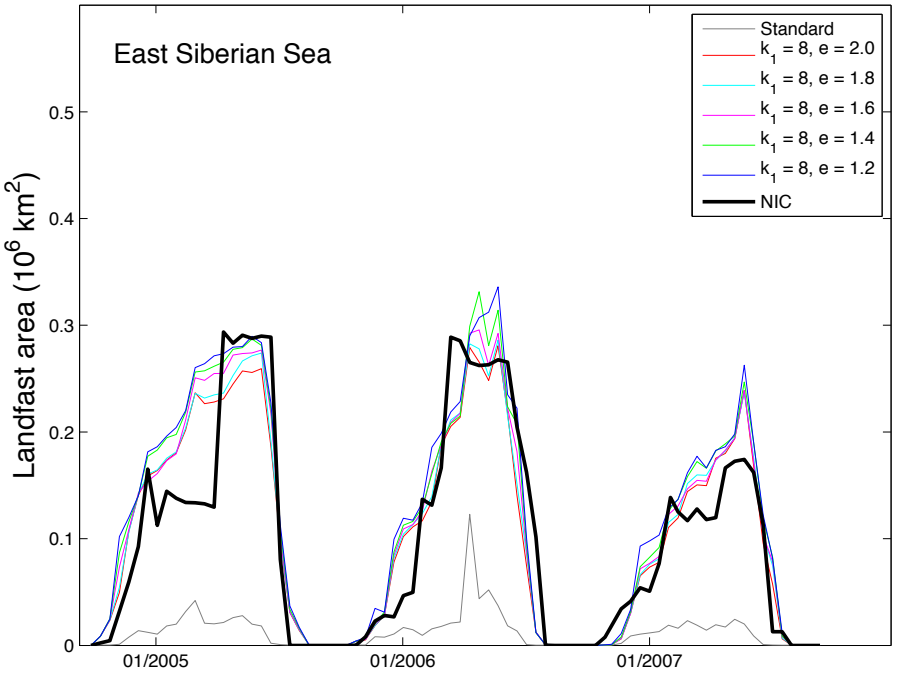



## Winter (January) 2015 tidal ellipse (M2) in the ice



# Increased tensile strength to promote landfast ice in deep water



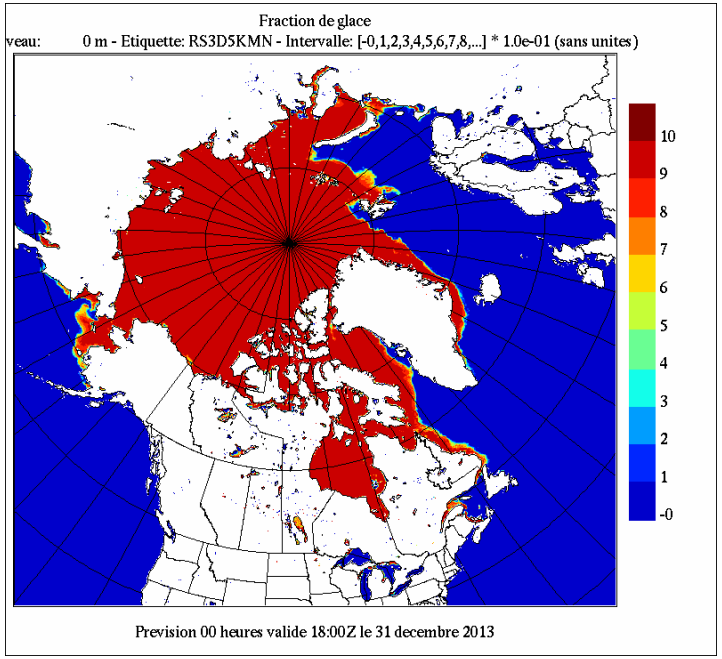

Lemieux et al., in prep.

# 3D-Var ice concentration analysis

- 0.045° (~ 5.0 km) resolution
- 4 analyses per day (00, 06, 12, 18 UTC)

- Analysis system (Buehner et al. 2014)
  - 3D-Var method
  - background = persistence (6 h earlier)
  - observation assimilated:
    - CIS image analyses, charts
    - SSM/I, SSM/IS
    - ASCAT
    - AMSR2
  - ice is removed where SST > 4°C
  - Ice field is corrected where analysis-error estimate is high

1768 × 1618 grid points



# Important physical processes
# 2) air-ice and ocean-ice stresses

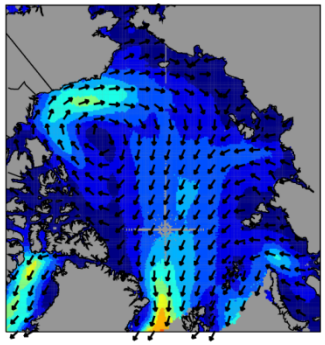
- as $\Delta z$ decreases, we need to reconsider how the ice-ocean stress is calculated (Roy et al. 2015).

- Ice roughness should be consistent with the one used for the atmospheric forcing (Roy et al. 2015).

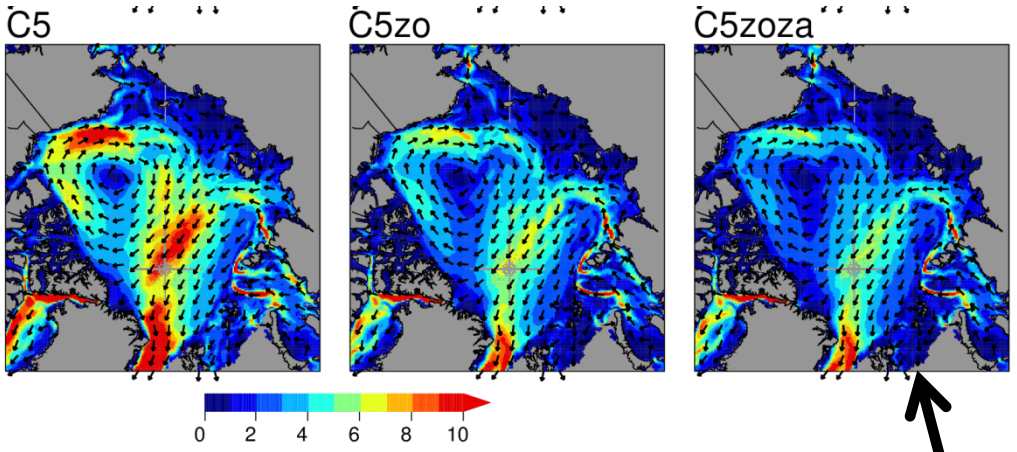
- air-ice and ice-ocean stresses should take into account both the skin drag and the form drag (Lupkes et al. 2012, Tsamados et al. 2014).

# Improved ice drifts with more realistic surface stresses

NSIDC



MODEL

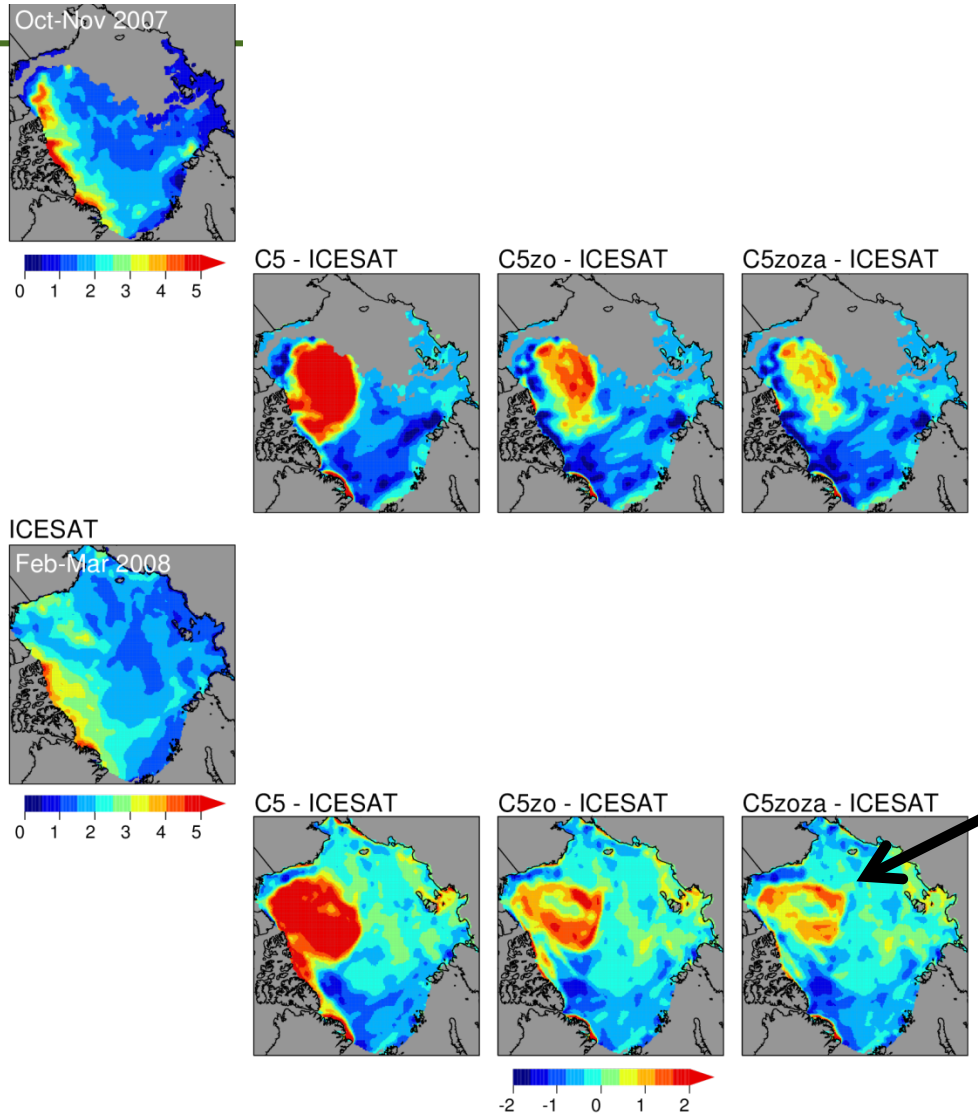



CICE4

More realistic ice-ocean roughness reduces overestimation

Roy et al. 2015

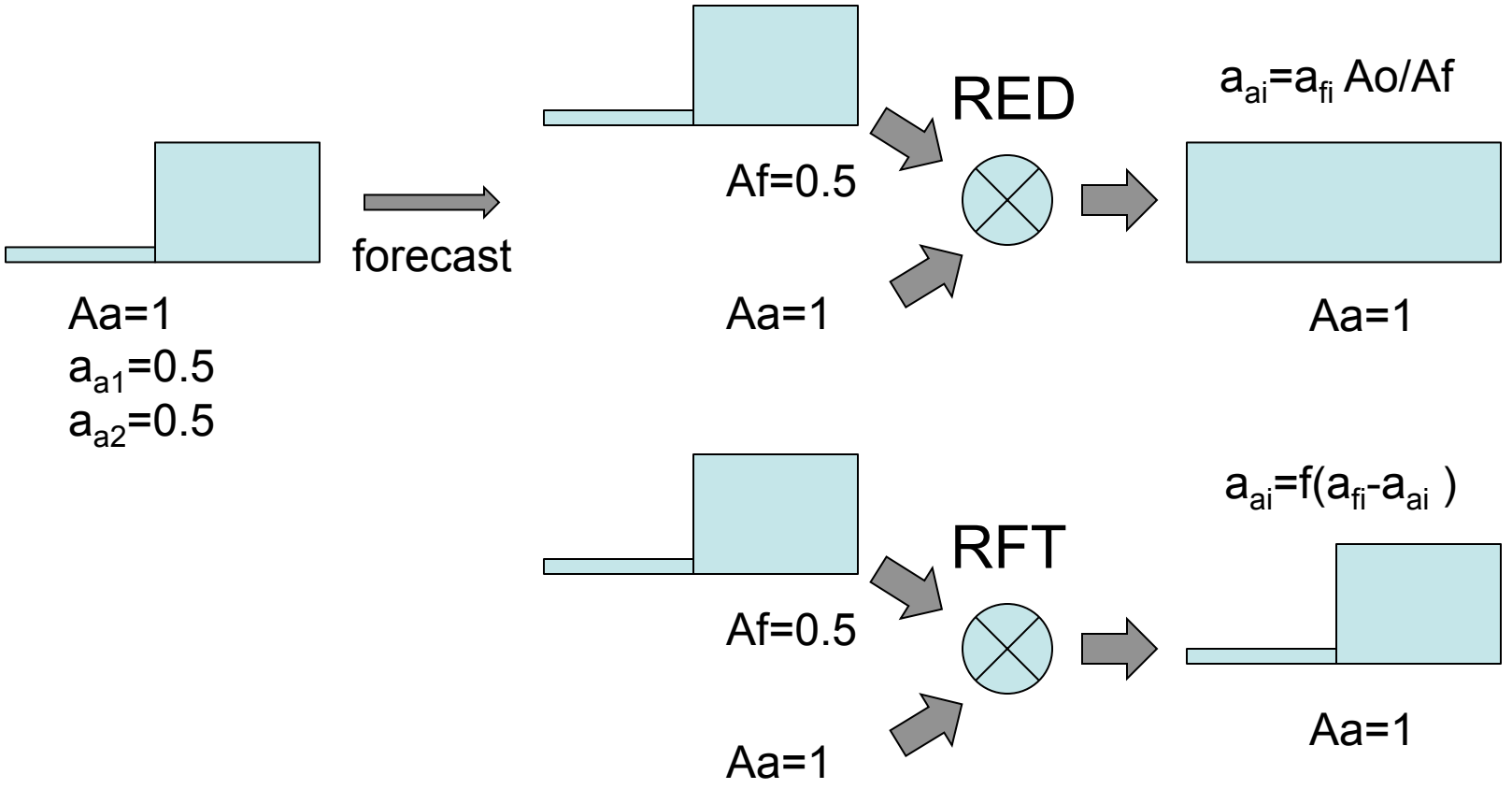
# Improved ice thickness with more realistic surface stresses




More realistic ice-ocean roughness reduces overestimation

Roy et al. 2015

# Correcting the ITD with the ice concentration analysis

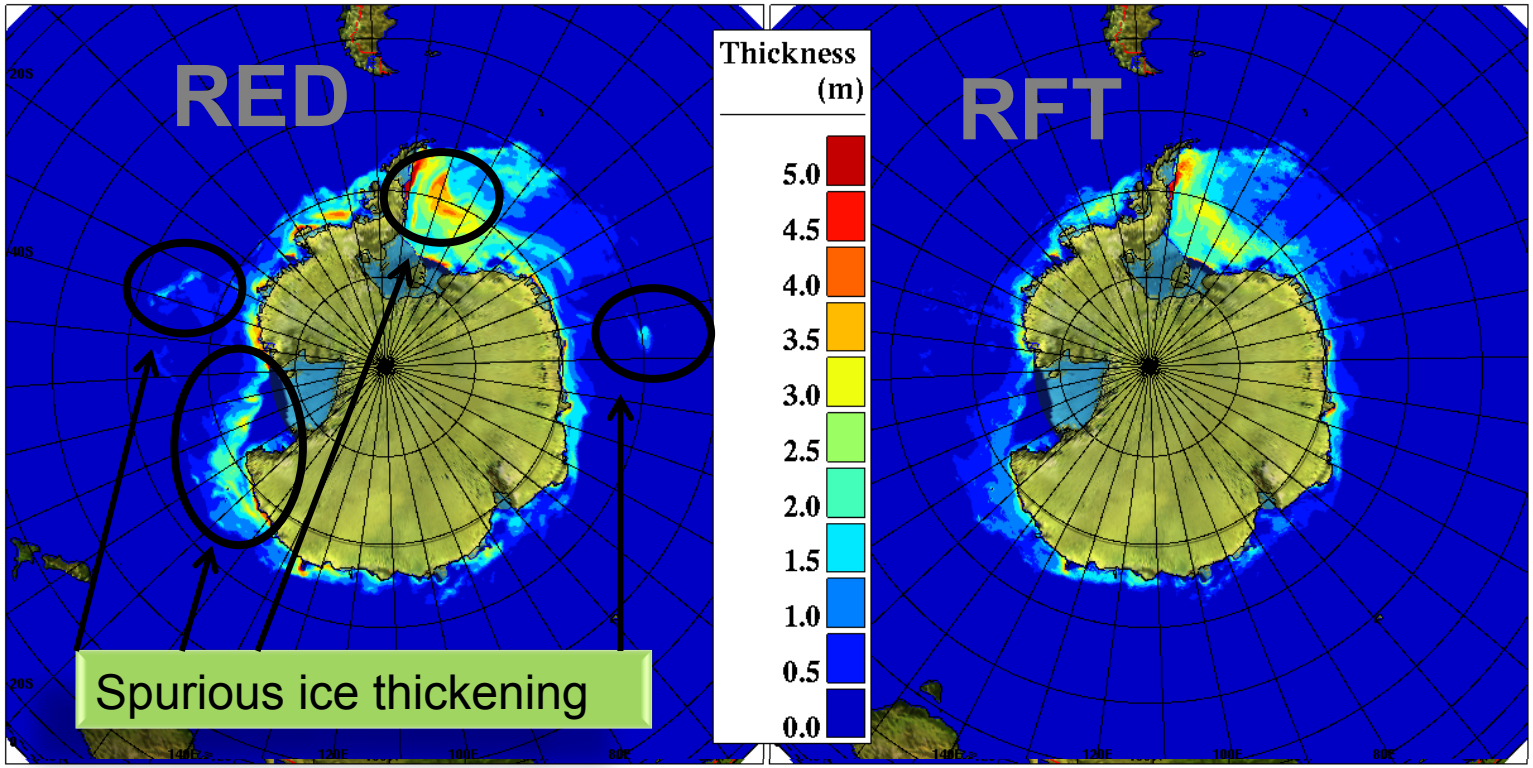



RED: Rescaled Existing Distribution

RFT: Rescaled Forecast Tendencies

Smith et al., QJRMS, 2015

# Rescaling using existing ITD (RED) or using forecast tendencies (RFT)




Smith et al., QJRMS, 2015